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Published in:
Antennas and Propagation Society International Symposium

Publication date:
1970

Document Version
Publisher's PDF, also known as Version of record

VII.2 - 9:00 A.M., Wednesday, 131 Hitchcock Hall

NEAR-FIELD MEASUREMENTS USING DIRECTIVE ANTENNAS

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The problem of determining the far field of an antenna by computation when the near-field pattern is the measured quantity has stimulated several investigations in recent years[1-8]. The importance of the problem rests mainly on the fact that the minimum distance required for a far-field measurement often turns out to exceed the length of the measurement range available.

In principle, the far-field pattern of an antenna can be determined to a given accuracy at any measurement distance by direct measurement, provided the antenna with which the measurement is made is sufficiently directive. A compressed measurement range which utilizes this technique has been described recently by Johnson[6].

Application of a moderately directive near-field probe in connection with subsequent computation for determining the far-field pattern has been reported by Brown and Jull[2]. The theory in [2] applies to two-dimensional antennas and makes use of cylindrical mode expansions of the radiated field.

A three-dimensional method using a spherical mode representation for the unknown field has been considered by James and Longdon[3]. This method uses omnidirectional probes (short dipoles and loops) in order to measure the near field directly, and is based on the knowledge of the radial components of the electric and magnetic near field. Near-field far-field transformations using spherical wave expansions in connection with measurement of tangential electric fields have been investigated by Ludwig[8].

In this paper, a far-field prediction method is presented in which a measuring antenna of arbitrary directivity (B in fig. 1) is assumed. This is specified through the (known) expansion of its field into spherical vector-wave functions centered at O'. The unknown antenna A (not shown) is centered at O and described in terms of spherical modes with the unknown coefficients a^{mn} and b^{mn}.

The theoretical derivation is based on the Lorentz reciprocity theorem

$$(1) \quad \int_S (\bar{E}_A \times \bar{H}_B - \bar{E}_B \times \bar{H}_A) \cdot d\bar{a} = 0$$

Here, $(\bar{E}_A, \bar{H}_A)$ is the field which exists when antenna A is used as a transmitting antenna and B is receiving. This field consists of the following three parts: 1) The field incident on B. 2) The field transmitted in the waveguide behind B. 3) The field reflected from B. Similarly, $(\bar{E}_B, \bar{H}_B)$ is the field which exists when B is transmitting and A is receiving.

The surface of integration S in (1) is composed of the two spherical surfaces S_1 and S_2 and a reference plane S_3 in the waveguide of B. The three surfaces are assumed to be interconnected in a manner suitable to enclose the source-free region between A and B.

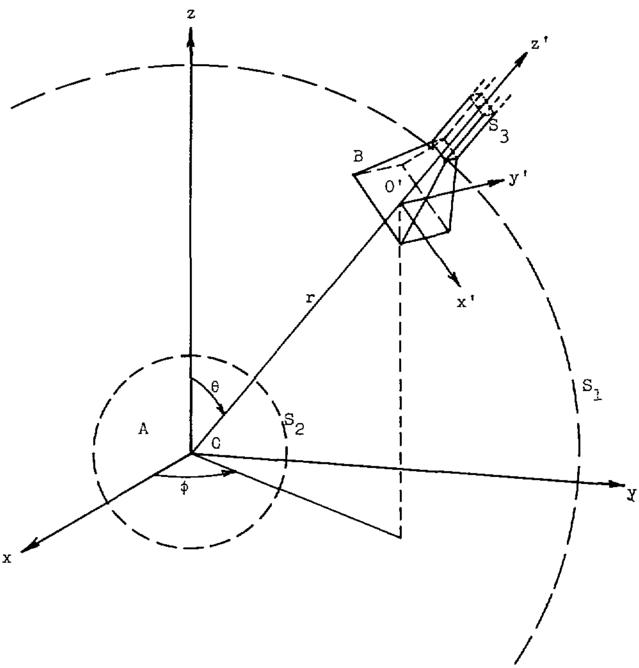

Fig. 1. Positions of antennas A and B and surfaces of integration S_1, S_2, S_3.

The contribution to (1) from the waveguide reference plane S_3 yields the signal $W(r,\theta,\phi)$ received by B when A transmits. The contribution from S_1 tends to zero as the radius of S_1 is expanded towards infinity. Calculation of the contribution from S_2 is the crucial step and involves application of the rather complicated translation and rotation theorems for the spherical vector wave functions[9,10].

The final result upon insertion in (1) is an equation of the following form

$$(2) \qquad \sum_{m,n} \left[a^{mn} f_{mn}(r,\theta,\phi) + b^{mn} g_{mn}(r,\theta,\phi)\right] = W(r,\theta,\phi)$$

where $-n \leq m \leq n$, $1 \leq n < \infty$. The functions f_{mn} and g_{mn} are involved functions details of which will be given in the paper. In the simple case where B is an x'-oriented short dipole eq.(2) simplifies to

$$(3) \qquad \sum_{m,n} \left[a^{mn}(\bar{M}_{mn}(r,\theta,\phi))_\theta + b^{mn}(\bar{N}_{mn}(r,\theta,\phi))_\theta\right] = W(r,\theta,\phi)$$

where $\bar{M}$ and $\bar{N}$ are the ordinary spherical vector wave functions. The left-hand side of eq.(3) is simply the θ-component at (r,θ,ϕ) of the electric near field from A.

Equation (2) forms the main result of the paper. It is assumed that the left-hand side may be truncated to a finite number of terms, k. Thus, if W is measured at k different positions (r,θ,ϕ), a system of k linear equations in the k unknown coefficients a^{mn} and b^{mn} is formed. Upon solution of this system the field from A is known everywhere.

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